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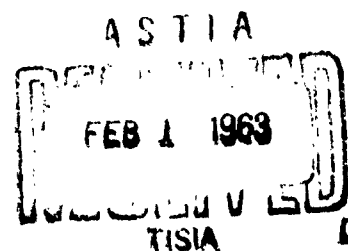
**OPTIMUM NUMBER AND TYPE OF STATIC DISCHARGERS
FOR T-33 AND F-100 JET AIRCRAFT**

**TECHNICAL DOCUMENTARY REPORT ASD-TDR-62-814
September 1962**

**Electromagnetic Warfare and Communications Laboratory
Aeronautical Systems Division
Air Force Systems Command
Wright-Patterson Air Force Base, Ohio**

Project No. 4357, Task No. 435706

**(Prepared under Contract No. AF 33(657)-8440
by Gayston Corporation, Dayton, Ohio
Authors: P. H. Stone, Jr. and R. H. Kuhbender)**



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FOREWORD

This report was prepared by Paul H. Stone, Jr. and Ralph H. Kuhbander of Gayston Corporation, Dayton, Ohio on Air Force Contract AF33(657)8440; Project No. 4357, Task No. 435706. The work was administered under the direction of the Adverse Weather Branch, Aeronautical Systems Division, Project Rough Rider 1962; Captain L. B. Marshall, Task Force Commander.

Mr. R. H. Kuhbander accompanied Project Rough Rider to Tinker AFB, Oklahoma and served as technical consultant with regard to diverter dischargers.

The authors wish to gratefully acknowledge the support and assistance offered by all of the Rough Rider Task Force Personnel. Among these are: Captain L. B. Marshall, Captain Joseph Kondracki, Captain Harvey J. Royer, First Lt. George P. Roys, James E. Taylor, V. L. Rollofson, and H. J. Maurer.

The authors wish to further acknowledge the cooperation offered by Mr. Bartman and Mr. Austin of the Electromagnetic Warfare and Communications Laboratory, ASD. Their foresight in referring this matter to Project Rough Rider has made this valuable information possible.

ABSTRACT

The purpose of the work undertaken was to determine the effectiveness of the Model 601 diverter discharger with regard to static dissipation and lightning protection. It was a further purpose of this work to determine the optimum number of dischargers for the specific aircraft being used.

To accomplish this, eight different configurations were planned for the F-100 aircraft and the T-33 aircraft. These plans were then executed on the various flights conducted as part of Project Rough Rider at Tinker Air Force Base.

Use of the Model 601 static dischargers resulted in considerable improvement in communications and the dischargers diverted lightning from the aircraft proper on many of the flights. The improvement in static level was particularly significant since the level of intensity of the storms was at a new high for aircraft penetration.

It is the recommendation of this report that combination diverter dischargers of the type used during the test flights, be adopted for use on all aircraft.

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I. INTRODUCTION

The requirement of all weather flying for military aircraft has intensified the problem of eliminating or materially reducing precipitation static to insure uninterrupted communications. All weather flying also has increased the occurrence of lightning damage to the aircraft. Figure 1 illustrates typical lightning damage to unprotected aircraft.

In the study of these problems it became increasingly evident to personnel at Gayston Corporation that the most effective solution would be a device that combined static dissipation with lightning diversion.

Gayston Corporation utilized previous experience in the static discharger field to develop a discharger tip material that would furnish the increased strength necessary for withstanding the buffeting present in high speed flying.

With regard to lightning diversion the most feasible approach seemed to be the graded resistance diverter pioneered by Lightning & Transients Research Institute, Minneapolis, Minnesota, under previous Air Force contracts.

However, it was apparent that the use of graded resistance paint or other type coating did not provide suitable life for diverters. Thus Gayston developed a permanent graded resistance solid body that could not be punctured to become noisy.

The results of the above were combined in the spring of 1961. An extra heavy aluminum mounting bracket that could withstand burning was added and the finished item was designated as a combination diverter - discharger, Gayston Corporation Model 601.

This product was presented to Communications Laboratory personnel and at their suggestion it was discussed at length with Captain L. B. Marshall of the Adverse Weather Branch, ASD, USAF.

Gayston Corporation then offered to equip the B-66 aircraft that was to participate in the 1961 Project Rough Rider Thunderstorm Tests at MacDill Air Force Base, Florida. This offer was accepted and, at no cost to the Government, the aircraft was equipped with 27 Model 601 diverter dischargers.

Results of the 1961 Project Rough Rider indicated that the dischargers provided significant improvement in the level of precipitation static encountered and considerable reduction in lightning strikes on the aircraft proper.

Consequently, Contract AF33(657)-8440 was awarded by the Air Force to Gayston Corporation specifically to further the study of Natural Interference Control Techniques during Project Rough Rider 1962. In addition, Model 601 Diverter Dischargers were to be flight tested and laboratory tested during Project Rough Rider.

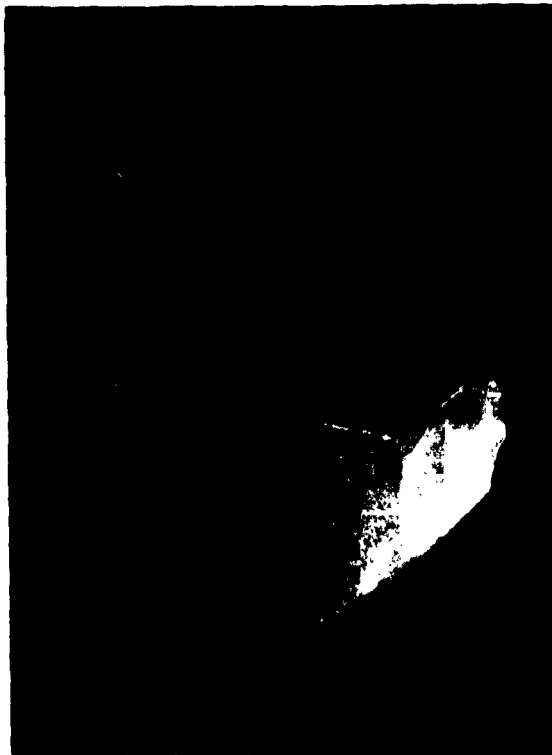
Laboratory studies were conducted both at Gayston Corporation and Lightning & Transients Research Institute to determine the capabilities of the diverter discharger and to plan configurations for mounting these dischargers for penetration flights during 1962 Project Rough Rider at Tinker AFB. The F-100 and T-33 aircraft were utilized.

Following the completion of storm penetration flights at Tinker AFB, the F-100 aircraft was flown to Boston, Massachusetts for a series of storm flights. A representative of Gayston Corporation accompanied the Task Force on this trip in order that diverter dischargers could be tested further.

The purposes of this report are:

1. To determine the static discharger and lightning diversion capabilities of the Model 601 diverter discharger.
2. To determine the optimum number and placement of the Model 601 on jet aircraft.
3. To provide flight test data relative to the severity and magnitude of the electromagnetic field during flight penetration of storms.

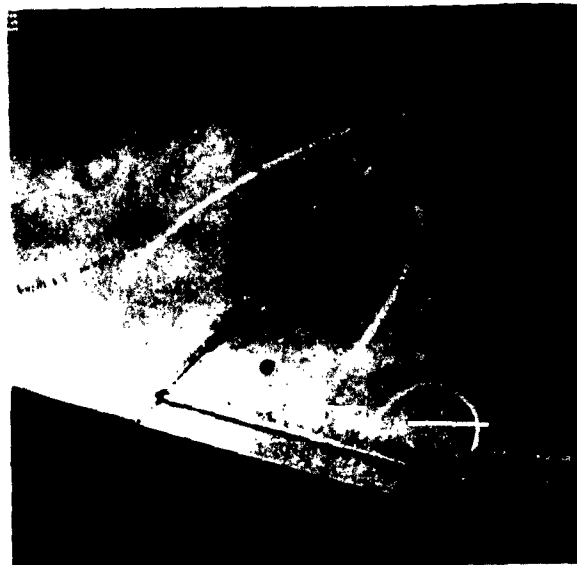
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Wing Tip Damage



Energy transfer from lightning completely melted metal of wing slat.



Moveable fins welded to main frame by lightning strike

Lightning Damage to Unprotected Aircraft
Figure 1

II. MODEL 601 DIVERTER DISCHARGER

The Model 601 has been developed for use on high speed aircraft to accomplish two objectives:

1. It serves as a lightning diverter.
2. It dissipates precipitation static electricity noiselessly, causing no radio interference.

These objectives are discussed individually below.

Lightning Diversion

The Model 601 diverter is a graded resistance diverter. The principle of graded resistance for this purpose is not new, however the ability to make a permanently conductive graded resistance diverter is new. The purpose is accomplished without the use of resistance paints or other surface coatings; rather it is permanently conductive in each of the resistance ranges and no puncturing can occur.

An approaching stroke of lightning produces an electric field non linearity along the graded resistance thus causing a localized streamering and attracting the stroke. The stroke is attracted to the tip of the diverter and when it connects to the tip 90% of the voltage between the lightning stroke and the aircraft is across the end section of the diverter due to the diverter action with the other diverter sections. This high local gradient induces a flashover on the tip section. As the lightning stroke contacts each successive graded resistance section, 90% of the voltage is still across the next section contacted by the stroke and thus the lightning stroke moves from section to section along the diverter to the base.[†]

Proper placement of the Model 601 lightning diverter will cause lightning strokes to be guided past critical areas and divert them to non-critical areas.

Note that the tip of the diverter is replaceable as discussed later in this summary and is replaced easily if required.

Total weight of the diverter discharger is 2.6 ounces.

Static Dissipation

The Model 601 is designed to mount on the trailing edge of the aircraft wings and tail section in the manner of AN/ASA-3C wicks. It is constructed to withstand high speed windstreams and buffeting.

The diverter discharger consists of three basic parts: the mounting bracket, the body, and the tip. The mounting bracket and body are considered to be permanent parts and the tip is replaced readily in the field.

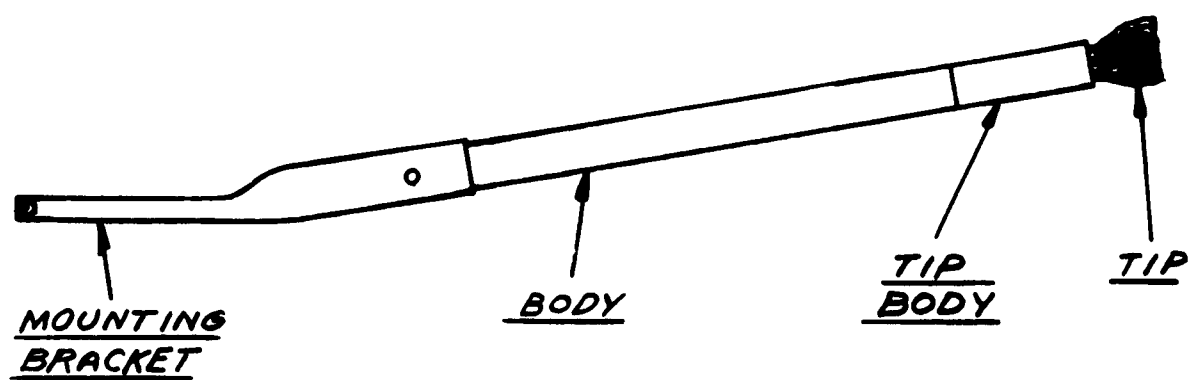
Figure 2 illustrates this diverter discharger.

The Mounting Bracket

The mounting bracket of the Model 601 diverter discharger is made from aluminum tubing 5/8" OD x .065" wall thickness, alloy 6061T6. This provides extra heavy aluminum which can withstand the burning that accompanies lightning diversion.

This bracket is equipped with two mounting holes at present and can be altered easily to permit affixing with an epoxy resin bonding agent if desired. The resin must be a conductive resin to provide a current path for static dissipation.

[†] References are listed at the end of the report.



Model 601 Diverter Discharger

Figure 2

The Body

The two piece body consists of the main body with three permanently conductive flexible sections, varying in resistance as previously defined, and the tip body containing the fourth resistance section. These sections are permanently conductive, cannot wash out, and will withstand extreme high and low temperatures without deterioration. Their flexibility will avoid breaking that might result from careless handling, and will provide personnel safety. This is an extremely rugged assembly containing no sharp points or rigid protrusions.

The body of this diverter discharger is permanent and under all normal operating conditions will seldom require replacement.

The Tip

The tip of the Model 601 diverter discharger is made of multiple stranded high strength nylon, arranged for assembly with the body.

The tip is constructed to withstand high speed buffeting and heavy precipitation conditions. The nylon strands have been made very short in length to avoid excessive whipping and have been suitably impregnated against water washout.

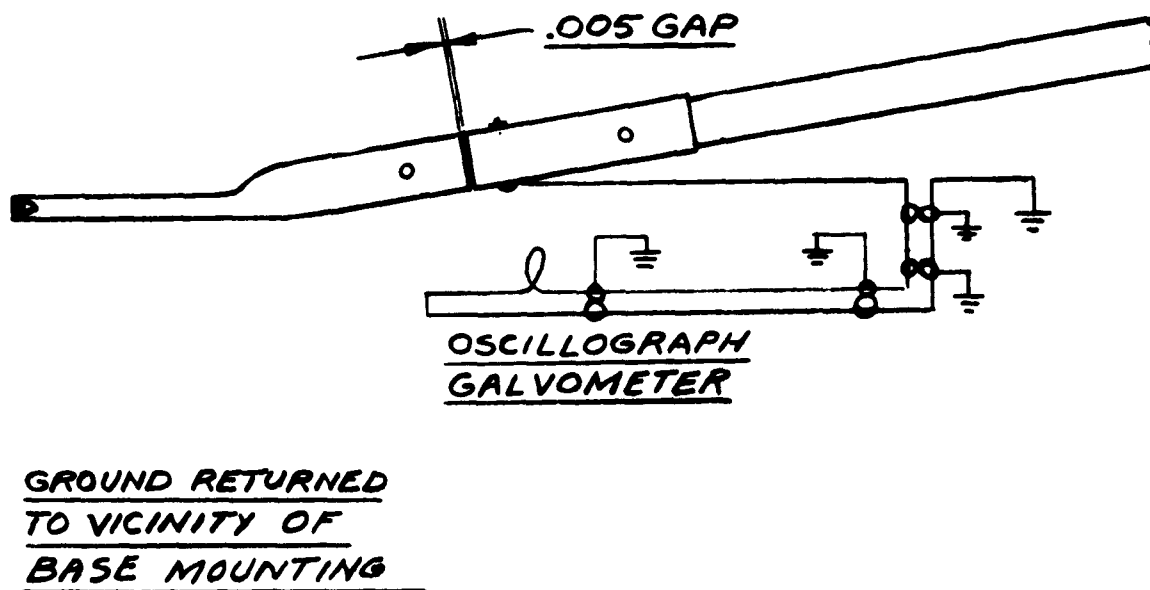
Dischargers can be made using the material in the body without nylon strands which will dissipate precipitation static. However, they will not discharge at a suitable radio frequency noise level (under 50 microvolts throughout the voltage range).

Thus the nylon strands in the tip are indispensable. Consequently efforts have been made to shorten the tip strands to a minimum length and to obtain high level impregnation for adequate service life.

This tip is replaceable in the field without special tools, requiring a minimum of maintenance labor.

Instrumenting the Model 601 Diverter Discharger

In order to measure current output of the discharger in actual service, instrumentation personnel of ASD developed the method shown in figure 3. Instrumented dischargers were manufactured by Gayston in accordance with this method, and were used during storm penetration flights as described elsewhere in this report.



Instrumented Model 601 Diverter Discharger

Figure 3

III. BACKGROUND FLIGHT TEST INFORMATION

Project Rough Rider 1961 - - MacDill AFB, Florida

Listed below is a summary of storm penetrations and results particularly with regard to static dissipation and lightning damage.

Type of Aircraft - B-66

Inclusive dates of program - Sept. 12, 1961 to Oct. 10, 1961

Number of flights - 16

Total Storm penetrations - 133

TABLE 1. FLIGHT RECAPITULATION

<u>Date</u>	<u>Penetrations</u>	<u>Precipitations</u>	<u>Precipitation Static</u>	<u>Lightning Damage</u>
9-14-61	10	Light to Mod.	Mod.	None
9-15-61	2	Light	Mod. to Heavy	None
9-17-61	12	Light	Mod. to Heavy	None
9-20-61	9	Light	Mod.	None
9-22-61	16	Mod.	Mod. to Heavy	None
9-26-61	16	Mod. to Heavy	Mod. to Heavy	Small burned holes in right wing tip. Charred Tips.
9-29-61	20	Light to Mod.	Mod. to Heavy	None
9-30-61	6	Mod. to Heavy	Heavy - Severe	None
10-3-61	15	Mod.	Mod. to Heavy	None
10-4-61	6	Mod.	Mod.	None
10-7-61	11	Light to Mod.	Mod. to Heavy	None
10-9-61	10	Light to Mod.	Mod.	None

Diverter Discharger Data

Total Dischargers mounted - 27.

Locations - 6 on each wing, 4 on each horizontal stabilator, 5 on the vertical stabilizer, and 2 on the rear turret.

Instrumentation - The second discharger inboard from the left wing tip was connected to an oscillograph in order that current dissipation could be measured.

Instrumentation Readings

Maximum current recorded - 125 microamps.

Current exceeded 100 microamps on 3 penetrations.

Current exceeded 50 microamps on 18 penetrations.

It is estimated that the discharger mounted on the outboard wing tips dissipated in excess of 150 microamps on several penetrations.

Precipitation static varied from moderate to heavy throughout the program. It is significant to note that communication was never lost, and that while the pilot felt that the precipitation static that existed was annoying, it did not degrade radio reception. On previous storm penetration tests, precipitation static caused loss of communications.

It is possible that the precipitation static resulted partially from cross fields that may have been present in the thunderstorms. Static dischargers do not materially reduce precipitation static resulting from cross fields since the entire aircraft discharges at sharp points to produce rapidly varying radio noise.

Lightning strikes on the aircraft proper were greatly controlled as compared to previous storm penetration flights. The diverter dischargers successfully diverted most of the lightning strikes.

The dischargers mounted outboard on the wings and stabilators were charred on the tips and the mounting brackets were burned while they were successfully diverting the lightning. The only damage to the aircraft proper was one small hole in the wing tip. See Figure 4.

Conclusions

The diverter dischargers performed very well in both diverting lightning and dissipation static.

An insufficient quantity of dischargers was used for the size of the B-66 aircraft.

The outboard diverter discharger on each wing and stabilator should be mounted as close to the tip extremity as possible. This is essential for both lightning protection and static elimination.

III. BACKGROUND FLIGHT TEST INFORMATION

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Listed below is a summary of storm penetrations and results particularly with regard to static dissipation and lightning damage.

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9-20-61	9	Light	Mod.	None
9-22-61	16	Mod.	Mod. to Heavy	None
9-26-61	16	Mod. to Heavy	Mod. to Heavy	Small burned holes in right wing tip. Charred Tips.
9-29-61	20	Light to Mod.	Mod. to Heavy	None
9-30-61	6	Mod. to Heavy	Heavy - Severe	None
10-3-61	15	Mod.	Mod. to Heavy	None
10-4-61	6	Mod.	Mod.	None
10-7-61	11	Light to Mod.	Mod. to Heavy	None
10-9-61	10	Light to Mod.	Mod.	None

Diverter Discharger Data

Total Dischargers mounted - 27.

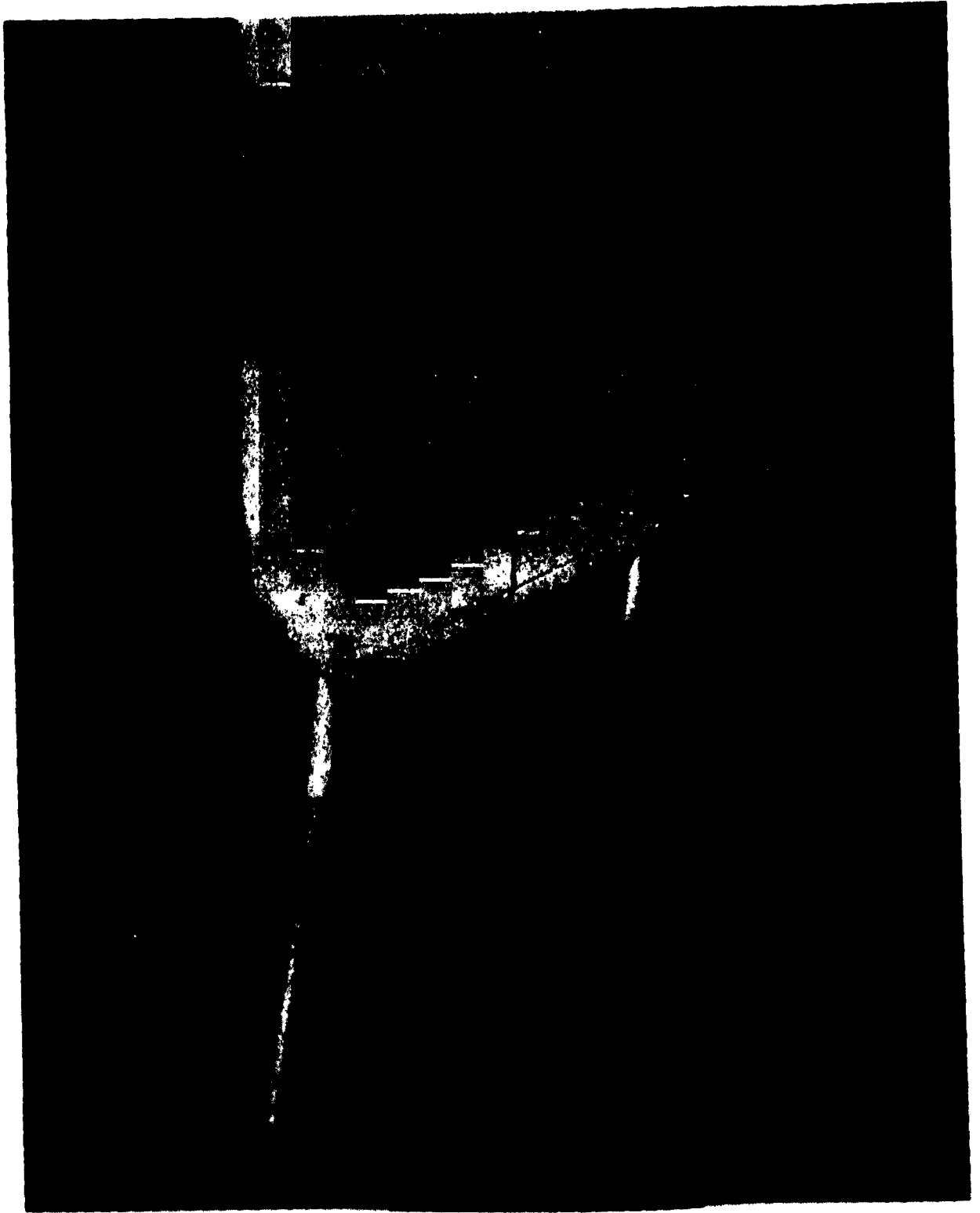
Locations - 6 on each wing, 4 on each horizontal stabilator, 5 on the vertical stabilizer, and 2 on the rear turret.

Instrumentation - The second discharger inboard from the left wing tip was connected to an oscillograph in order that current dissipation could be measured.

Instrumentation Readings

Maximum current recorded - 125 microamps.

Current exceeded 100 microamps on 3 penetrations.



Lightning Damage to Diverter and Wing Tip
MacDill AFB, Florida
Figure 4

IV. LABORATORY FINDINGS

Gayston Laboratory Study

A number of tests were conducted at the Gayston Laboratory to determine effectiveness, current capacity, and optimum use of Model 601 diverter dischargers with regard to static dissipation. Results of these tests follow.

Maximum Current Dissipation

The Model 601 discharger was found to be capable of dissipating 5 milliamperes of current at 50,000 volts without damage or deterioration occurring. Currents in excess of 5 milliamperes produced light streamering from the body of the 601 dischargers. This test was performed by affixing the diverter discharger to the output of a 50,000 volt power supply, and positioning the discharger near a ground post. The gap to ground was then varied and output current readings were listed.

Current Values and Radio Frequency Noise Values at Various Voltages

Table 2 lists typical performance values of the Model 601 diverter discharger at voltages from 5,000 to 40,000 volts of applied voltage. The electrical test setup is shown in Figure 5. The range of voltage used does not necessarily cover the complete range of aircraft charge encountered in flight. This range was used to permit comparison with the requirements of Specification MIL-S-9129A.

TABLE 2. TYPICAL PERFORMANCE VALUES

Model 601 Diverter Discharger

APPLIED VOLTAGE	CURRENT	RF NOISE
<u>KV</u>	<u>Microamp</u>	<u>Microvolt</u>
10	1.5	Under 10
15	4.7	Under 10
20	10.3	10
25	17.0	10
30	28.0	10
35	42.0	20
40	61.0	20

Wick Spacing

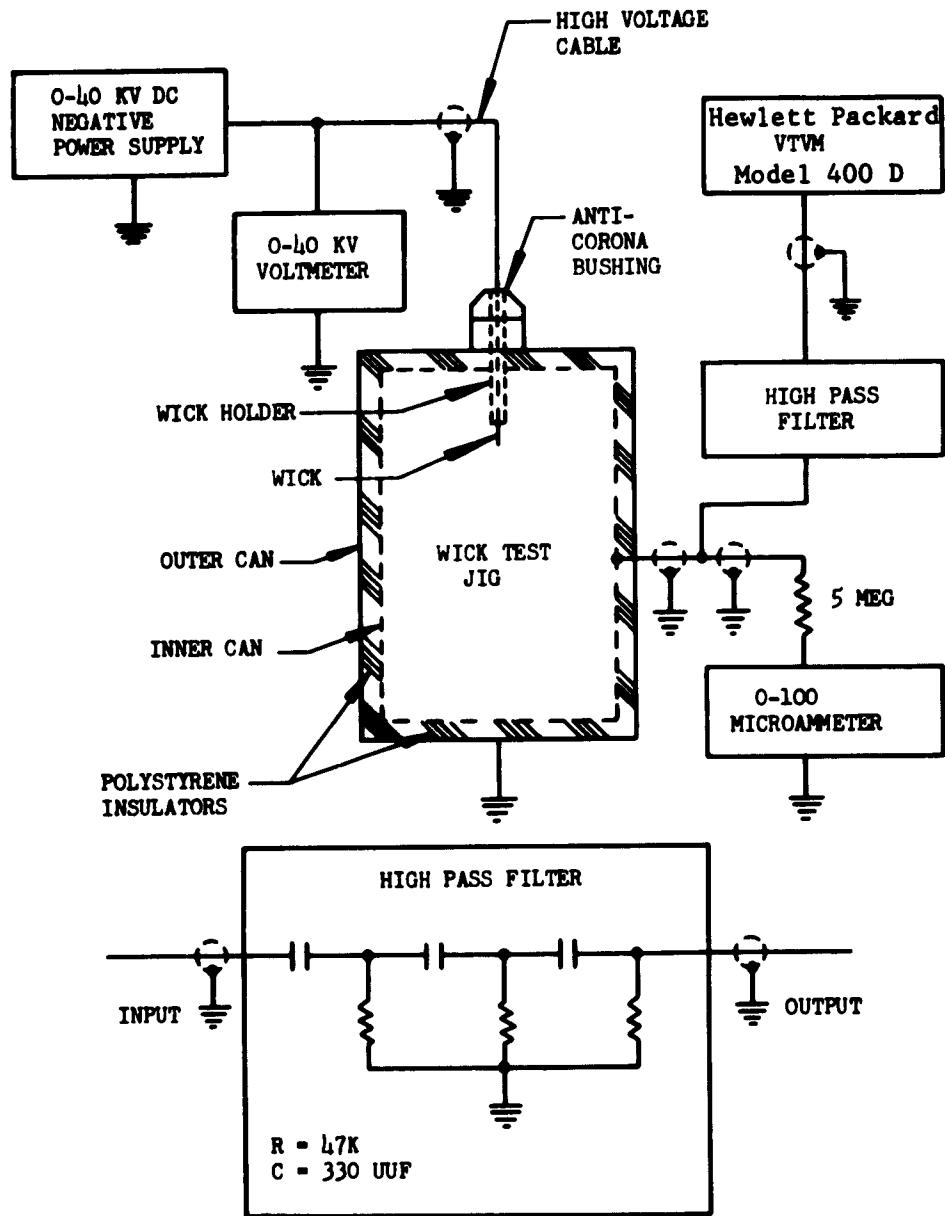
To determine most effective location spacing for dischargers, a horizontal stabilator from an F-100 aircraft was suspended in the air and a charge of 40,000 volts was introduced. Locations and quantities of dischargers were then varied and current output was recorded. See Figure 6.

This current output was recorded by using instrumented dischargers as defined under Section II.

Results of these tests were as follows:

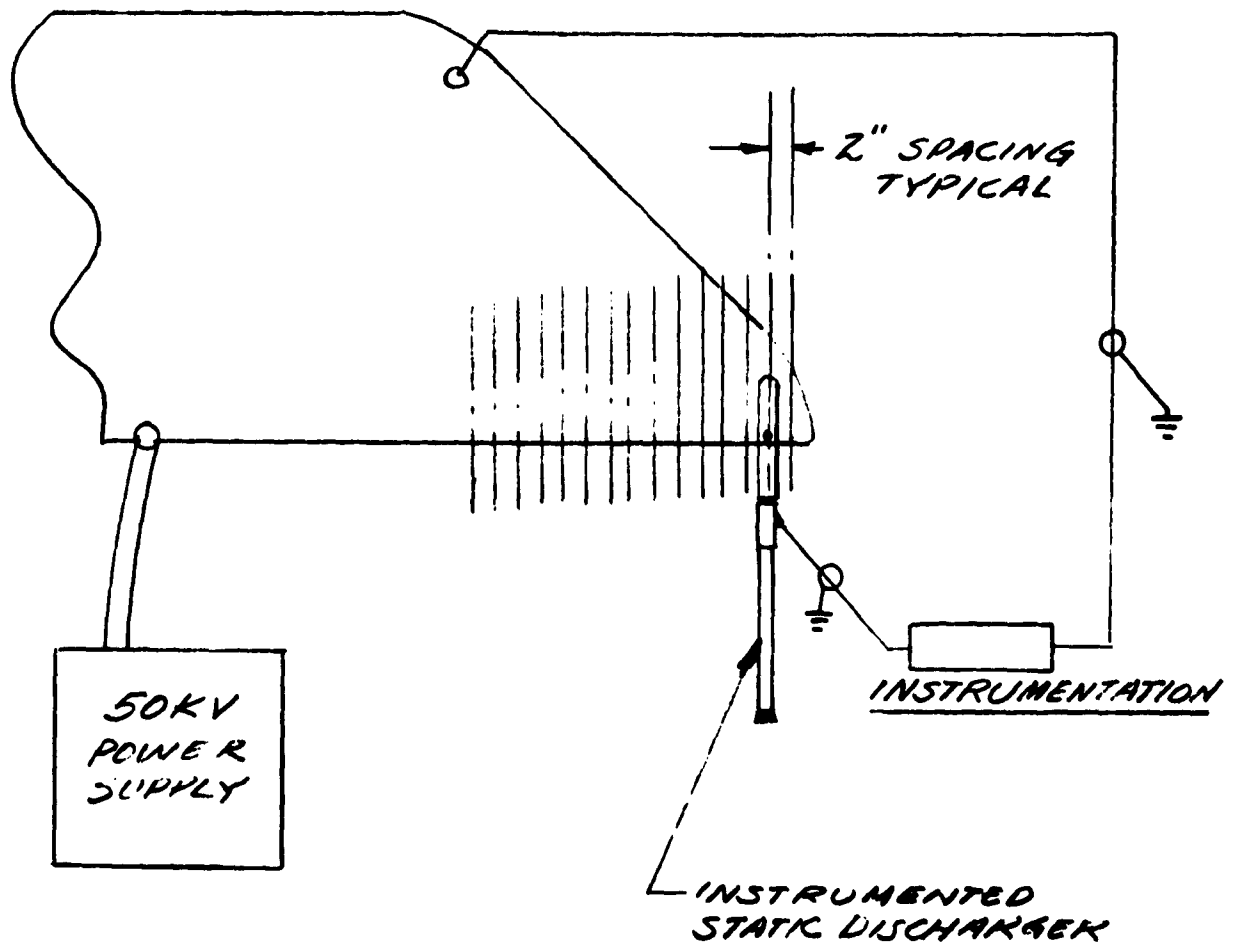
Minimum Spacing of Dischargers 3" -

Note: Closer spacing resulted in dischargers attempting to combine, thus causing two dischargers to perform very little better than one discharger.



Test Setup
Current & RF Noise Readings

Figure 5



Test Setup - Current Dissipation
and Discharger Spacing

Figure 6

Maximum spacing recommended - 6"
Preferred location -

Dischargers should be mounted so that they start as far outboard on the wing tips and horizontal stabilator tips as possible.

Dischargers should be mounted so that they are spaced 4" to 5" apart inboard through the area of wing to the flaps and through 40 to 50% of each horizontal stabilator.

One discharger should be mounted as close to the upper vertical stabilizer tip as possible. Spacing of 4" to 5" should be used for dischargers on this stabilizer.

Tests At The Lightning and Transients Research Laboratory

Static Dissipation Tests

Model 601 diverter dischargers were tested for current dissipation under wind stream conditions along with conventional wick type dischargers. All dischargers dissipated at a satisfactory rate. However, the conventional type discharger could not withstand the wind buffeting. The Model 601 discharger was not damaged by the wind stream.

Model 601 diverter dischargers were tested for radio frequency noise level in the method described in ASD Technical Note 61-163 prepared by Lightning & Transients Research Institute.

This discharger performed very well under these conditions. The discharger was tested with two sizes of nylon tip. Results of these tests are shown in Table 3.

The conclusion from these tests is that the Model 601 is a satisfactory static discharger that is capable of withstanding wind buffeting experienced in high speed aircraft.

TABLE 3. Performance Values Model 601 Diverter Discharger

Model - 601 Large Tip - OD

<u>Potential KV</u>	<u>Discharge Current Microamp</u>	<u>Radio Frequency Noise Micro volt</u>
14 14	1.0	
20	2.0	Too low
30	5.0	to read
40	9.0	
50	15.0	
60	18.0	

Model 601 Standard Tip - OD

<u>Potential KV</u>	<u>Discharge Current Microamp</u>	<u>Radio Frequency Noise Micro volt</u>
12	1.0	2.5
20	3.0	2.5
30	7.0	2.7
40	14.0	2.8
50	20.5	2.8
60	27.0	2.9

Lightning Tests

Tests were conducted to simulate lightning damage suffered by the Model 601 diverter dischargers used on Project Rough Rider 1961 at MacDill AFB, Florida.

Results indicated that 1,300,000 volts and 200 amperes of current transferred 80 coulombs of electricity in the actual lightning strike. See Figure 7.

Lightning strikes were applied to Model 601 diverter dischargers along with other style dischargers.

The Model 601 discharger showed some burning of tip material and some vaporization of aluminum mounting base. However, static dissipation ability still was present.

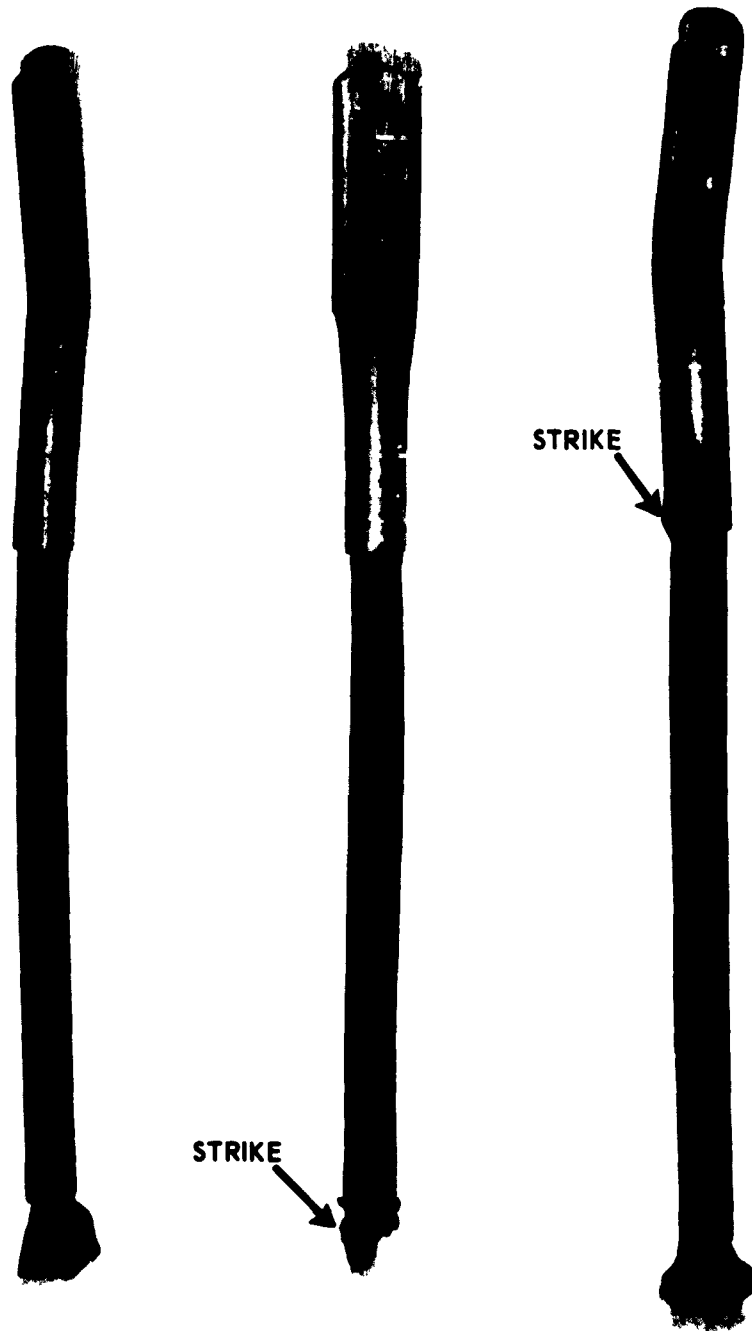
Lightning strikes were applied to the Model 601 diverter discharger to evaluate performance as a lightning diverter. The diverter discharger performed satisfactorily as a lightning diverter with strike voltages as high as 1,800,000 volts.

While approximately 50% of the strikes caused loss of tip and thus loss of static dissipation function, the diverter remained intact with regard to lightning protection.

Conclusions -

The Model 601 diverter discharger furnishes static dissipation ability and provides lightning protection to the aircraft. Even following the lightning strike that blows off the tip, complete service can be restored by installing a new tip, as described in Section II of this report.

The large size tip is recommended for use since it permits more tip damage by lightning without loss of static dissipation ability.



Simulation of Lightning Strike
on Diverter Discharger at
Lightning and Transients Research Institute
Figure 7

V. FLIGHT TEST PROGRAM

Project Rough Rider 1962 - Tinker AFB, Oklahoma

This project was conducted from May 5, 1962 through June 5, 1962. Two aircraft, an F-100 and a T-33, were utilized.

<u>Aircraft</u>	<u>Total Flights</u>	<u>Total Penetrations</u>
F-100	12	41
T-33	<u>12</u>	<u>63</u>
Total.....	24	104

TABLE 4
FLIGHT RECAPITULATION
F-100

<u>Date of Flight</u>	<u>No. of Penetrations</u>	<u>Precip. Hail. Turb.</u>	<u>Lightning</u>	<u>Static Level</u>	
April 19	(These 3 flights flown from WP AFB behind Tankers, etc. No appreciable data collected)				
April 24					
April 27					
May 5		Light prec. No hail. Light turb.	Some lightning, no strikes.	Mod. to heavy	Static clear for 2 min.
May 8	4	Mod. hail. Mod. prec.	Some lightning. LW1	Mod. to heavy Improved.	
May 20 FL#1	6	Prec. heavy to Mod. Some hail. Mod. turb	Mod. lightning. LW1	Mod. heavy on edge of clouds.	No trouble receiving.
May 20 FL#2	4	Heavy prec. Heavy turb. Little hail	Several strikes. Heavy lightning. LW1-RW2-RS1	Mod.	Arc to wing tip.
May 24	2	Mod. prec. turb. Mild to mod. hail.	Mod. lightning no strikes	1 blind area, comm. lost. Mod. to light	
May 31 FL#1	6	Heavy lightning, soft hail, light to med. turb.	No strikes	Mod.	Strike on radar probe.
May 31 FL#2	4	Some hail, mod. turb light prec. Heavy lightning.	No strikes.	Mod. Some heavy in blow-off.	
June 2	8	Light turb, light to mod. prec, no lightning.	No strikes.	Mod. improved.	
June 5	4	Heavy lightning, mod. to heavy prec. Heavy turb.	RW1-RW2-LW1-LW2-RS1-LS1-LS2-VS2-VS1	Strongest storm. Greatly improved.	Static light.

TOTAL..... 41

16

TABLE 4 (Continued)
FLIGHT RECAPITULATION
T-33

Date of Flight	No. of Penetrations	Precip. Hail, Turb.	Lightning	Static Level	
April 19	(Flown at WPAFB	B - no appreciable data collected.)			
May 8	4	Heavy hail, mod. to heavy hail.	LW1-Antenna	Mod. to heavy, no trouble receiving.	
May 20 FL#1	6	Some icing, some heavy turb, light to mod. prec.	Mod. No strikes.	Moderate to heavy.	
May 20 FL#2	2	Light prec, light turb, light hail, some icing.	Heavy lightning. No strikes.	Mod. to heavy	
May 22 FL#1	9	Heavy lightning, mod. prec, mod. turb, sometimes heavy.	No strikes.	Mod.	
May 22 FL#2	8	Mild storm	No strikes.	Light or none	
May 23	10	Very little lightning, mod. hail, mod. prec, some heavy turb.	No strikes.	Light to mod.	
May 24	4	Heavy hail, prec mod. to heavy, severe turb.	LW-1 RW-3	Light to mod.	
May 30	7	Heavy lightning, mod. hail. mod. prec.	R.T. & Antenna	Light to none	Foil vaporized
May 31 FL#1	3	Mod prec, mod. turb, little hail	Mod. lightning. Severe strikes RT LW1 LS2	Mod-light, sometimes no static.	Pilot calls strikes on plane.
May 31 FL#2	2	No hail, some heavy turb, mod. prec,	Heavy lightning, no strikes.	Some light to mod.	
June 5	8	Heavy hail. Heavy turb. Heavy prec. at times.	RW1 LW1	Little or none	

TOTAL..... 63

Configurations

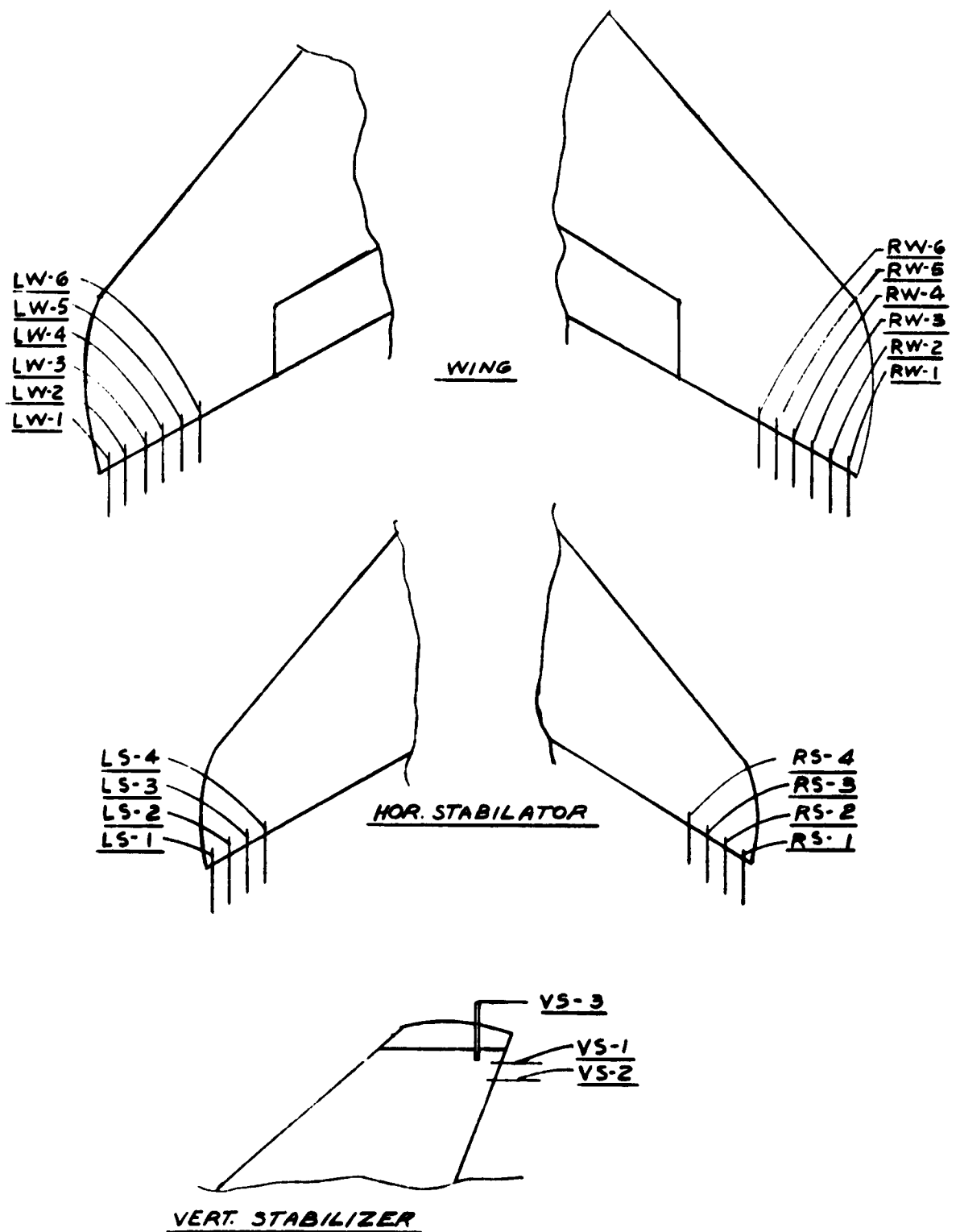
Figure 8 illustrates possible locations of diverter dischargers on the F-100.

Figure 9 illustrates possible locations of diverter dischargers on the T-33.

Tabulated in Tables 5 through 15 are the configurations used for each flight for each aircraft.

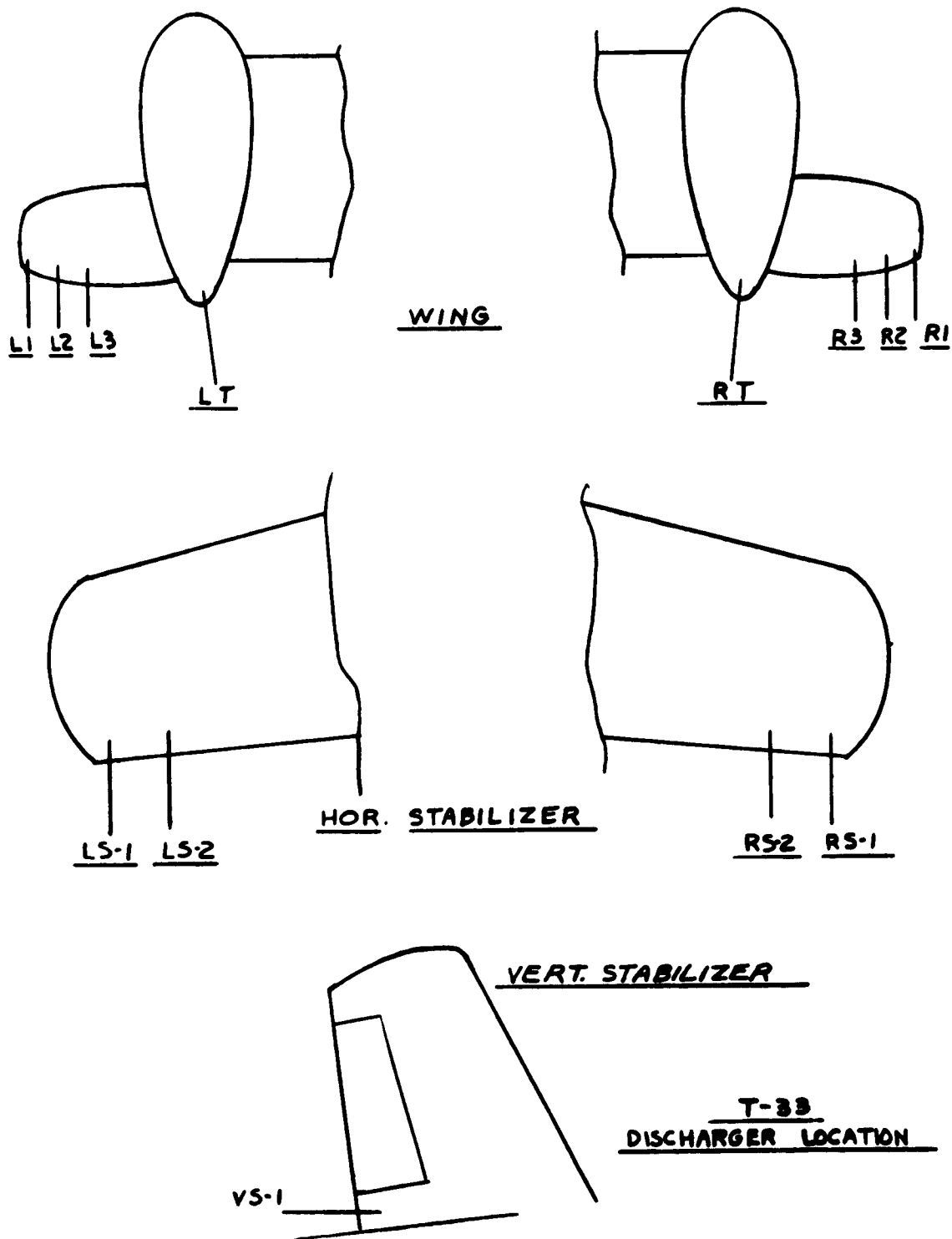
These Tables also show the positioning of instrumented dischargers. These dischargers were connected to an oscillograph in the manner shown in Figure 3. In addition an electrical field measuring device was connected to an oscillograph.

The data obtained from the above are not available at this time. However, it will be published as a portion of an ASD technical report prepared by Project Rough Rider personnel.



F-100
Discharger Location

Figure 8



T-33
Discharger Location

Figure 9

TABLE 5. POSITIONS OF DISCHARGERS

Date of Flight May 5

Configuration F-1

<u>F-100 Locations</u>	<u>Discharger</u>	<u>T-33 Locations</u>	<u>Discharger</u>
RW-1 Instrumented 601		RW-1	
RW-2 Blank		RW-2	
RW-3 Blank		RW-3	
RW-4 Instrumented 601		RT	
RW-5 Blank		LW-1	
RW-6 Instrumented 601		LW-2	
LW-1 Instrumented 601		LW-3	
LW-2 Blank		LT	
LW-3 Blank		RS-1	
LW-4 Instrumented 601		RS-2	
LW-5 Blank		LS-1	
LW-6 Instrumented 601		LS-2	
RS-1 Blank		VS	
RS-2 Blank			
RS-3 Blank			
RS-4 Blank			
LS-1 Blank			
LS-2 Blank			
LS-3 Blank			
LS-4 Blank			
VS-1 Blank			
VS-2 Instrumented 601			

TABLE 6. POSITIONS OF DISCHARGERS

Date of Flight May 8

Configuration F-2 & T-1

<u>F-100 Locations</u>	<u>Discharger</u>	<u>T-33 Locations</u>	<u>Discharger</u>
RW-1 Instrumented 601		RW-1 Instrumented 601	
RW-2 Standard 601		RW-2 Blank	
RW-3 Standard 601		RW-3 Blank	
RW-4 Instrumented 601		RT Instrumented 601	
RW-5 Standard 601		LW-1 Standard 601	
RW-6 Instrumented 601		LW-2 Blank	
LW-1 Instrumented 601		LW-3 Blank	
LW-2 Standard 601		LT Standard 601	
LW-3 Standard 601		RS-1 Blank	
LW-4 Instrumented 601		RS-2 Blank	
LW-5 Standard 601		LS-1 Blank	
LW-6 Instrumented 601		LS-2 Blank	
RS-1 Standard 601		VS Blank	
RS-2 Standard 601			
RS-3 Standard 601			
RS-4 Blank			
LS-1 Standard 601			
LS-2 Standard 601			
LS-3 Standard 601			
LS-4 Blank			
VS-1 Blank			
VS-2 Blank			

TABLE 7. POSITIONS OF DISCHARGERS

Date of Flight May 20 - Flights 1 & 2

Configuration T-2 & F-3

<u>F-100 Locations</u>	<u>Discharger</u>	<u>T-33 Locations</u>	<u>Discharger</u>
RW-1 Instrumented 601		RW-1 Instrumented 601	
RW-2 Standard 601		RW-2 Standard 601	
RW-3 Standard 601		RW-3 Blank	
RW-4 Instrumented 601		RT Instrumented 601	
RW-5 Standard 601		LW-1 Standard 601	
RW-6 Instrumented 601		LW-2 Standard 601	
LW-1 Instrumented 601		LW-3 Blank	
LW-2 Standard 601		LT Standard 601	
LW-3 Standard 601		RS-1 Blank	
LW-4 Instrumented 601		RS-2 Blank	
LW-5 Standard 601		LS-1 Blank	
LW-6 Instrumented 601		LS-2 Blank	
RS-1 Standard 601		VS Instrumented 601	
RS-2 Standard 601			
RS-3 Standard 601			
RS-4 Standard 601			
LS-1 Standard 601			
LS-2 Standard 601			
LS-3 Standard 601			
LS-4 Standard 601			
VS-1 Blank			
VS-2 Instrumented 601			

TABLE 8. POSITIONS OF DISCHARGERS

Date of Flight May 22 - Flights 1 & 2

Configuration T-3

<u>F-100 Locations</u>	<u>Discharger</u>	<u>T-33 Locations</u>	<u>Discharger</u>
RW-1		RW-1 Standard 601	
RW-2		RW-2 Instrumented 601	
RW-3		RW-3 Blank	
RW-4		RT Instrumented 601	
RW-5		LW-1 Standard 601	
RW-6		LW-2 Standard 601	
LW-1		LW-3 Blank	
LW-2		LT Standard 601	
LW-3		RS-1 Standard 601	
LW-4		RS-2 Blank	
LW-5		LS-1 Standard 601	
LW-6		LS-2 Blank	
RS-1		VS Standard 601	
RS-2			
RS-3			
RS-4			
LS-1			
LS-2			
LS-3			
LS-4			
VS-1			
VS-2			

TABLE 9. POSITIONS OF DISCHARGER

Date of Flight May 23

Configuration T-4

F-100 Locations	Discharger	T-33 Locations	Discharger
RW-1		RW-1 Standard 601	
RW-2		RW-2 Instrumented 601	
RW-3		RW-3 Standard 601	
RW-4		RT Instrumented 601	
RW-5		LW-1 Standard 601	
RW-6		LW-2 Standard 601	
LW-1		LW-3 Standard 601	
LW-2		LT Standard 601	
LW-3		RS-1 Standard 601	
LW-4		RS-2 Blank	
LW-5		LS-1 Standard 601	
LW-6		LS-2 Blank	
RS-1		VS Standard 601	
RS-2			
RS-3			
RS-4			
LS-1			
LS-2			
LS-3			
LS-4			
VS-1			
VS-2			

TABLE 10. POSITIONS OF DISCHARGERS

Date of Flight May 24

Configuration F-4 & T-4

<u>F-100 Locations</u>	<u>Discharger</u>	<u>T-33 Locations</u>	<u>Discharger</u>
RW-1 Standard 601		RW-1 Standard 601	
RW-2 Instrumented 601		RW-2 Instrumented 601	
RW-3 Standard 601		RW-3 Standard 601	
RW-4 Instrumented 601		RT Instrumented 601	
RW-5 Standard 601		LW-1 Standard 601	
RW-6 Instrumented 601		LW-2 Standard 601	
LW-1 Standard 601		LW-3 Standard 601	
LW-2 Instrumented 601		LT Standard 601	
LW-3 Standard 601		RS-1 Standard 601	
LW-4 Instrumented 601		RS-2 Blank	
LW-5 Standard 601		LS-1 Standard 601	
LW-6 Instrumented 601		LS-2 Blank	
RS-1 Standard 601		VS Standard 601	
RS-2 Standard 601			
RS-3 Standard 601			
RS-4 Standard 601			
LS-1 Standard 601			
LS-2 Standard 601			
LS-3 Standard 601			
LS-4 Standard 601			
VS-1 Blank			
VS-2 Instrumented 601			

TABLE 11. POSITIONS OF DISCHARGERS

Date of Flight May 30

Configuration T-4

<u>F-100 Locations</u>	<u>Discharger</u>	<u>T-33 Locations</u>	<u>Discharger</u>
RW-1		RW-1 Standard 601	
RW-2		RW-2 Instrumented 601	
RW-3		RW-3 Standard 601	
RW-4		RT Instrumented 601	
RW-5		LW-1 Standard 601	
RW-6		LW-2 Standard 601	
LW-1		LW-3 Standard 601	
LW-2		LT Standard 601	
LW-3		RS-1 Standard 601	
LW-4		RS-2 Blank	
LW-5		LS-1 Standard 601	
LW-6		LS-2 Blank	
RS-1		VS Standard 601	
RS-2			
RS-3			
RS-4			
LS-1			
LS-2			
LS-3			
LS-4			
VS-1			
VS-2			

TABLE 12. POSITIONS OF DISCHARGERS

Date of Flight May 31 - 1st Flight

Configuration F-5 & T-5

<u>F-100 Locations</u>	<u>Discharger</u>	<u>T-33 Locations</u>	<u>Discharger</u>
RW-1 Standard 601		RW-1 Standard 601	
RW-2 Instrumented 601		RW-2 Instrumented 601	
RW-3 Instrumented 601		RW-3 Standard 601	
RW-4 Standard 601		RT Instrumented 601	
RW-5 Instrumented 601		LW-1 Standard 601	
RW-6 Standard 601		LW-2 Standard 601	
LW-1 Standard 601		LW-3 Standard 601	
LW-2 Instrumented 601		LT Standard 601	
LW-3 Instrumented 601		RS-1 Standard 601	
LW-4 Standard 601		RS-2 Standard 601	
LW-5 Instrumented 601		LS-1 Standard 601	
LW-6 Standard 601		LS-2 Standard 601	
RS-1 Standard 601		VS Standard 601	
RS-2 Standard 601			
RS-3 Standard 601			
RS-4 Standard 601			
LS-1 Standard 601			
LS-2 Standard 601			
LS-3 Standard 601			
LS-4 Standard 601			
VS-1 Standard 601			
VS-2 Instrumented 601			

TABLE 13. POSITIONS OF DISCHARGERS

Date of Flight May 31 - 2nd Flight

Configuration F-5 & T-5

F-100 Locations	Discharger	T-33 Locations	Discharger
RW-1 Standard 601		RW-1 Standard 601	
RW-2 Instrumented 601		RW-2 Instrumented 601	
RW-3 Instrumented 601		RW-3 Standard 601	
RW-4 Standard 601		RT Instrumented 601	
RW-5 Instrumented 601		LW-1 Standard 601	
RW-6 Standard 601		LW-2 Standard 601	
LW-1 Standard 601		LW-3 Standard 601	
LW-2 Instrumented 601		LT Standard 601	
LW-3 Instrumented 601		RS-1 Standard 601	
LW-4 Standard 601		RS-2 Standard 601	
LW-5 Instrumented 601		LS-1 Standard 601	
LW-6 Standard 601		LS-2 Standard 601	
RS-1 Standard 601		VS Standard 601	
RS-2 Standard 601			
RS-3 Standard 601			
RS-4 Standard 601			
LS-1 Standard 601			
LS-2 Standard 601			
LS-3 Standard 601			
LS-4 Standard 601			
VS-1 Standard 601			
VS-2 Instrumented 601			

TABLE 14. POSITIONS OF DISCHARGERS

Date of Flight June 2

Configuration F-6

<u>F-100 Locations</u>	<u>Discharger</u>	<u>T-33 Locations</u>	<u>Discharger</u>
RW-1 Standard 601		RW-1	
RW-2 Instrumented 601		RW-2	
RW-3 Instrumented 601		RW-3	
RW-4 Standard 601		RT	
RW-5 Instrumented 601		LW-1	
RW-6 Standard 601		LW-2	
LW-1 Standard 601		LW-3	
LW-2 Instrumented 601		LT	
LW-3 Instrumented 601		RS-1	
LW-4 Standard 601		RS-2	
LW-5 Instrumented 601		LS-1	
LW-6 Standard 601		LS-2	
RS-1 Standard 601		VS	
RS-2 Standard 601			
RS-3 Standard 601			
RS-4 Standard 601			
LS-1 Standard 601			
LS-2 Standard 601			
LS-3 Standard 601			
LS-4 Standard 601			
VS-1 Standard 601			
VS-2 Instrumented 601			

TABLE 15. POSITIONS OF DISCHARGERS

Date of Flight June 5

Configuration F-7 & T-5

<u>F-100 Locations</u>	<u>Discharger</u>	<u>T-33 Locations</u>	<u>Discharger</u>
RW-1 Standard 601		RW-1 Standard 601	
RW-2 Instrumented 601		RW-2 Instrumented 601	
RW-3 Instrumented 601		RW-3 Standard 601	
RW-4 Standard 601		RT Instrumented 601	
RW-5 Instrumented 601		LW-1 Standard 601	
RW-6 Standard 601		LW-2 Standard 601	
LW-1 Standard 601		LW-3 Standard 601	
LW-2 Instrumented 601		LT Standard 601	
LW-3 Instrumented 601		RS-1 Standard 601	
LW-4 Standard 601		RS-2 Standard 601	
LW-5 Instrumented 601		LS-1 Standard 601	
LW-6 Standard 601		LS-2 Standard 601	
RS-1 Standard 601		VS Standard 601	
RS-2 Standard 601			
RS-3 Standard 601			
RS-4 Standard 601			
LS-1 Standard 601			
LS-2 Standard 601			
LS-3 Standard 601			
LS-4 Standard 601			
VS-1 Standard 601			
VS-2 Instrumented 601			
VS-3 Standard 601			

The following descriptions outline occurrences and results of the storm penetrations for each aircraft.

T-33 Aircraft

Total configurations - 5
Minimum number of dischargers - 4
Maximum number of dischargers - 13

Static Dissipation Summary

When small quantities of dischargers were installed, precipitation static was moderate to heavy.

Installation of 13 static dischargers reduced precipitation static to either very light or none at all.

Lightning Diversion Summary

There were no lightning strikes on the aircraft proper except for those which pierced the plastic antenna cover at the top of the vertical stabilizer. This area definitely needs protection. Conductive foil was used to protect this area but it did not do an effective job. Figure 11 illustrates the damage to this area.

The diverters were struck by 10 severe lightning strikes. These strikes occurred at the locations listed below: (See Figure 9).

<u>Position</u>	<u>Number of Strikes</u>
RW1	1
RW3	1
RT	2
LW1	4
LW2	1
LS2	1

Figure 10 illustrates typical diverter damage.

Eight of the lightning strikes were severe enough to char the wicking in the tip or melt the edge of the aluminum mounting bracket.

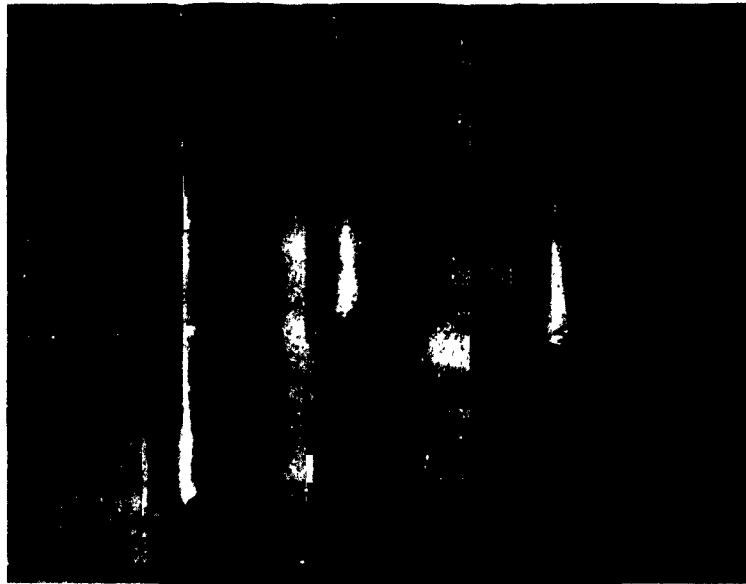
None of the diverter dischargers lost ability to dissipate precipitation static.

F-100 Aircraft

Total configurations - 8
Minimum number of dischargers - 7
Maximum number of dischargers - 23

Static Dissipation Summary

When small quantities of dischargers were used, precipitation static was heavy. VHF/UHF communications were not disrupted, but the static was very irritating to the pilot.



Typical Lightning Damage to
Diverter Dischargers at
Tinker AFB-Project Rough Rider 1962
Figure 10



Lightning Damage to Plastic Antenna Cover
Figure 11

Installation of 23 dischargers greatly improved the precipitation static level, but did not eliminate it completely.

The fins of the drop tanks were found to be a source of static. Two Model 601 diverter dischargers were mounted on the fins between flights. This again improved the level of precipitation static.

It is recommended that drop tanks and other such appurtenances be equipped with diverter dischargers.

Lightning Diversion Summary

There were no lightning strikes on the aircraft proper.

The diverters were struck by 15 severe lightning strikes. These strikes occurred at the locations listed below: (See Figure 8).

<u>Position</u>	<u>Number of Strikes</u>
RW-1	2
RW-2	2
LW-1	4
LW-2	1
RS-1	2
LS-1	1
LS-2	1
VS-2	1
VS-3	1

Figure 10 illustrates typical diverter damage.

Fourteen of the lightning strikes were severe enough to char the wicking in the tips or melt the edge of the aluminum mounting bracket.

None of the diverter dischargers lost ability to dissipate precipitation static.

Project Rough Rider 1962 - Hanscom Field, Massachusetts

Listed below is a summary of operations covering storm penetrations made.

Flights conducted - 2

Penetrations - 6

Type of Aircraft - F-100

Diverter Dischargers Mounted - 11

Location Pattern - See Table 16.

<u>Date of Flight</u>	<u>Penetrations</u>	<u>Precipitation</u> <u>Static</u>	<u>Precipitation</u> <u>Static</u>	<u>Lightning</u> <u>Damage</u>
July 11, 1962	0	(Instrument Checkout.....)		
July 12, 1962	6	Light		See Summary

Static Dissipation Summary

The static level was moderate to light with no loss of communications. Each of the three outboard dischargers on left wing was instrumented. Discharges measured from 100 to 125 microamperes on each discharger.

TABLE 16. POSITIONS OF DISCHARGERS

Date of Flight July 12

Configuration 1 at Hanscom Field

<u>F-100 Locations</u>	<u>Discharger</u>	<u>T-33 Locations</u>	<u>Discharger</u>
RW-1 Standard 601		RW-1	
RW-2 Instrumented 601		RW-2	
RW-3 Instrumented 601		RW-3	
RW-4 Standard 601		RT	
RW-5 Blank		LW-1	
RW-6 Blank		LW-2	
LW-1 Instrumented 601		LW-3	
LW-2 Instrumented 601		LT	
LW-3 Instrumented 601		RS-1	
LW-4 Standard 601		RS-2	
LW-5 Blank		LS-1	
LW-6 Blank		LS-2	
RS-1 Blank		VS	
RS-2 Blank			
RS-3 Blank			
RS-4 Blank			
LS-1 Blank			
LS-2 Blank			
LS-3 Blank			
LS-4 Blank			
VS-1 Instrumented 601			
VS-2 Standard 601			
VS-3 Standard 601			

Lightning Diversion Summary

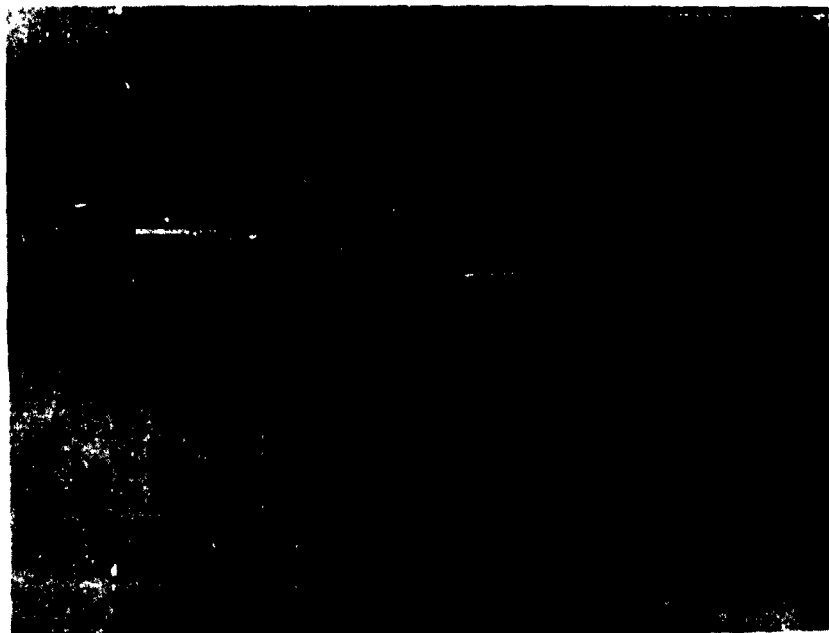
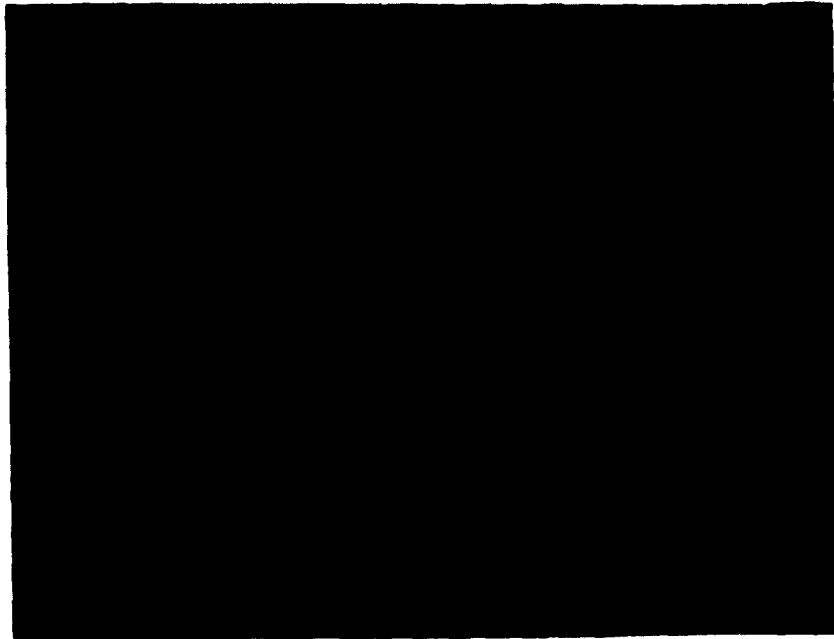
The F-100 aircraft was not equipped with diverter dischargers on the stabilators or the fin of the left camera tank.

The aircraft received two direct lightning strikes, one at the tip of right stabilator and one on the fin of the left camera tank. Figure 12 illustrates the damage suffered due to lack of diverter dischargers.

These strikes produced shocks which were felt by the copilot and caused some damage to the aircraft.

Other lightning was successfully diverted by the diverter dischargers. One strike diverted by the unit mounted outboard on the right wing tip caused charring of the diverter discharger tip and slight melting of the mounting bracket. However, this unit retained its ability both as a diverter and a discharger. (See Figure 13).

It is significant to note that the areas struck where no diverters were present during this flight, were protected completely during flights at Tinker AFB when diverters were present.



Damage to F-100 in Storm Penetration
at Hanscom Field, Mass.
No diverters mounted in area damaged
Figure 12



Lightning Damage to Diverter Discharger
Hanscom Field, Mass.
Figure 13

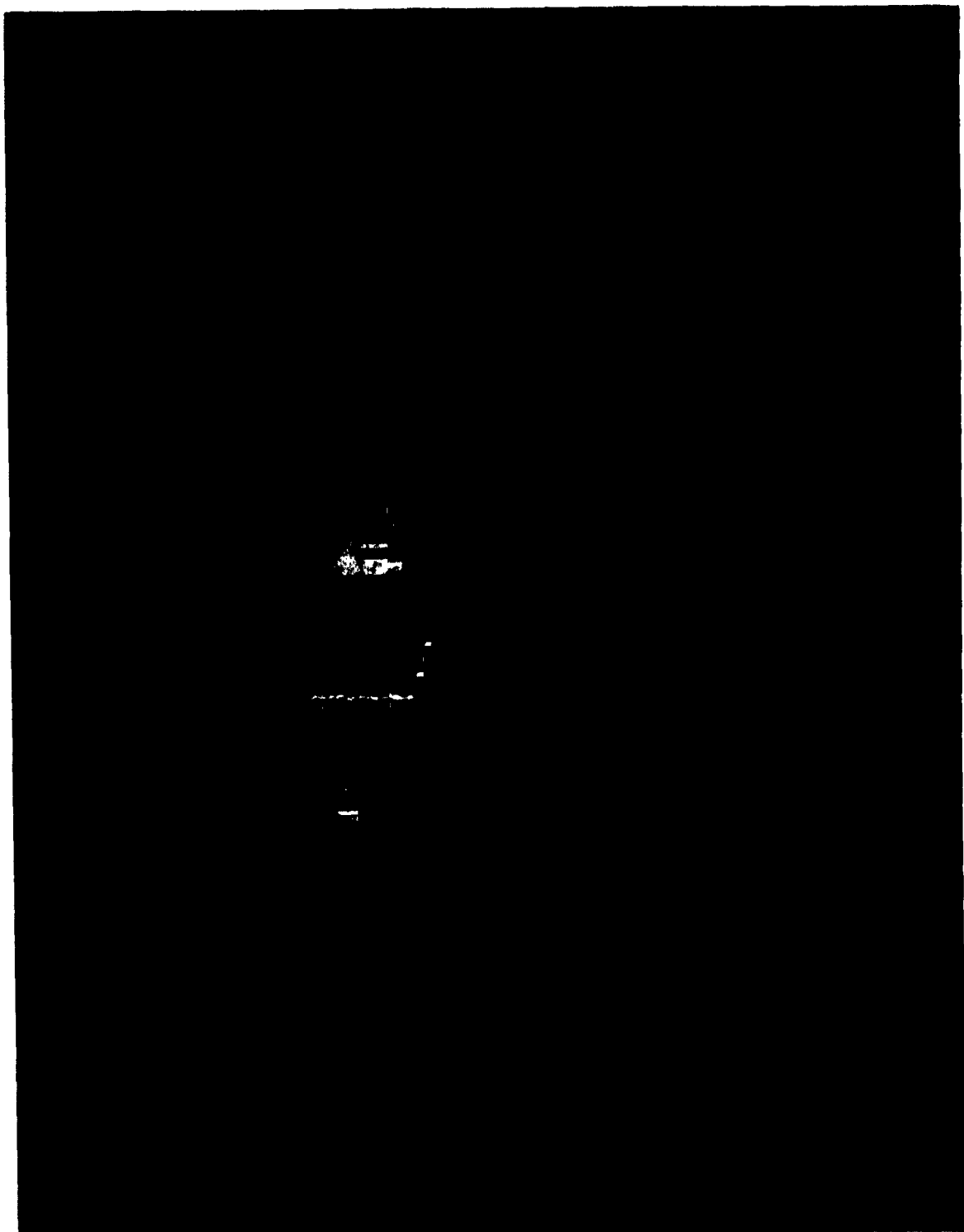
VI. CONCLUSIONS AND RECOMMENDATIONS

1. The Model 601 diverter discharger performed very adequately on both the T-33 and the F-100 throughout Project Rough Rider 1962.
2. The T-33 has less static interference than the F-100 due to the fact that more dischargers per unit size were used.
3. Optimum Number of Dischargers:
The number of dischargers required must be based upon weather conditions that are to be present. Consequently, two quantities are listed for each aircraft.
 - a. Based upon actual flight test experience, the optimum number of diverter dischargers required for the T-33 aircraft under (1) severe weather conditions is 13, and under (2) normal weather conditions is 7.
 - b. Based upon actual flight test experience, the optimum number of diverter dischargers required for the F-100 aircraft under (1) severe weather conditions is 21, and under (2) normal weather conditions is 10.
4. Location of Diverter Dischargers:
The diverter dischargers must be located in the following areas, the areas being listed in the order of their importance: (See Figures 8 and 9).
 - a. Extremity of Wing Tip - minimum of two diverter dischargers spaced 4" to 5" apart for each wing.
 - b. Extremity of Horizontal Stabilator Tip - minimum of one diverter discharger for each tip.
 - c. Vertical Stabilizer Tip - minimum of one diverter discharger located at the highest possible point, above antenna if possible.
 - d. Other diverter dischargers required are then provided at 4" to 5" spacing moving inboard on the wings and stabilator and down on the vertical stabilizer.
5. Fins of drop tanks and similar additional appurtenances produce corona and should carry at least two additional diverter dischargers each. This quantity is in addition to the optimum number listed in paragraph 3 above.
6. Use of diverter dischargers reduces lightning strikes on the aircraft proper to a negligible amount. For example, the two aircraft received only one small pin-point damage area on the aircraft proper, in 24 complete flights. This compares to strikes in excess of 100 suffered by the B-66 aircraft during project Rough Rider 1961 at Tinker AFB when diverter dischargers were not used.
7. Antenna covers need protection from lightning. The diverter discharger can provide this protection if an adequately strong mounting area can be provided. During Project Rough Rider 1962, the pilot received several shocks resulting from lightning striking the unprotected antenna cover. Lightning punctured the antenna cover and reached the antenna to produce these shocks. If this should occur during take-off or landing it could result in loss of aircraft.
8. Typical test data for dischargers used during Project Rough Rider 1962 are shown in Table 17. Test data before flights and after flight completions are shown. Testing was done by the method shown in Figure 5.
9. Figure 14 illustrates lightning damage to an aircraft used in storm penetrations with non-diverting static dischargers. A comparison of this picture with other pictures in this report clearly emphasizes the need for the protection offered by the combination Model 601 diverter discharger.

TABLE 17

Typical before and after test reports for Diverter Dischargers used on Rough Rider 1962.

Applied Voltage	<u>Before Flights</u> April 23, 1962		<u>After Flights</u> June 14, 1962		Sample No.
	Current Microamp	RF Noise Microvolt	Current Microamp	RF Noise Microvolt	
10	1.2	10	1.4	10	1
15	4.2	15	4.6	10	
20	9.0	15	9.7	10	
25	15.8	15	17.0	15	
30	24.0	20	26.0	20	
35	36.0	25	40.0	20	
40	57.0	25	63.0	20	
10	1.3	10	1.5	Under 10	2
15	4.3	10	4.8	Under 10	
20	9.1	10	10.0	10	
25	17.0	15	18.0	10	
30	26.0	15	28.0	10	
35	40.0	20	43.0	20	
40	57.0	25	61.0	20	
10	1.5	Under 10	1.8	Under 10	3
15	5.0	10	5.6	Under 10	
20	9.6	10	10.0	Under 10	
25	17.0	10	19.0	10	
30	28.0	15	29.0	15	
35	42.0	20	42.0	15	
40	58.0	20	60.0	15	
10	1.5	Under 10	0.7	Under 10	4 Struck by Lightning- May 20.
15	4.8	10	3.5	10	
20	10.0	15	9.0	10	
25	18.0	15	16.0	10	
30	25.0	15	26.0	20	
35	35.0	20	38.0	20	
40	56.0	20	52.0	25	
10	1.5	Under 10	0.2	Under 10	5 Struck by Lightning- May 31. Severe strike.
15	4.7	Under 10	1.8	Under 10	
20	10.3	10	5.7	Under 10	
25	17.0	10	11.6	Under 10	
30	28.0	10	18.0	15	
35	42.0	20	28.0	15	
40	61.0	20	42.0	20	



Lightning Damage in Storm Penetration using
non diverter type discharger. (discharger has been removed)
Figure 14

REFERENCES

1. M. M. Newman, J. D. Robb, J. R. Stahmann - "Lightning Protection for Aircraft", Lightning and Transients Research Institute Report 334, page 6 (December 1956).
2. M. M. Newman, J. D. Robb, E. O. Nestvold, Ta Chen - "Equivalent Field Method for Testing Aircraft Static Dischargers" ASD-TDR-61-163, Lightning and Transients Research Institute L & T Report 396, (January 1962).

<div></div>	<div></div> <p>Aeronautical Systems Division, Dir/Avionics, Electro-magnetic Warfare & Communications Lab, Wright Patterson Air Force Base, Ohio.</p> <p>Report No. ASD-TDR-62-814 NATURAL INTERFERENCE CONTROL TECHNIQUES. Final Report, September 1962</p> <p>42 pages include illustrations, tables.</p> <p>Unclassified Report</p> <p>Detailed information on the effectiveness of a new type of static discharger - lightning diverter. This report includes laboratory findings and actual flight results during Project Rough Rider 1962.</p> <p>Optimum number of diverter dischargers required for various types of aircraft is included.</p> <p>Use of the diverter discharger on aircraft flying storm penetrations provided definite improvement in static dissipation with resulting improved radio communications; and provided lightning protection by diverting all lightning strikes from the aircraft proper.</p> <div></div>	<div></div> <p>1. Static dischargers</p> <p>2. Lightning arrestors</p> <p>3. Static eliminators</p> <p>I. AFSC Project No. 4357 Task 435706</p> <p>II. Contract AF33(657) 8440</p> <p>III. Gayston Corporation, Dayton, Ohio</p> <p>IV. P. H. Stone, Jr., R. H. Kuhbender</p> <p>V. Available for OTS</p> <p>VI. In ASTIA Collection</p> <p>UNCLASSIFIED</p>
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